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# A Gunn Oscillator, Detector, and Mixer Module for 24 GHz

The described construction can be used as Gunn oscillator or as detector/mixer in the 24 GHz amateur band. It is a further example of the use of bicycle valves (1) and the previously described choke system for contact-less tuning of waveguide modules. Common semiconductors manufactured by well-known firms such as Siemens, Microwave Associates, etc. are to be used in a waveguide type WR 28 (R 320).

The module partly consists of previously described parts such as a choke mount for the diode feed, and a choke arrangement for the tuning. The construction is very simple, but requires – as mentioned in previous articles – the use of a lathe.

## OPERATING BEHAVIOUR

Due to the high cut-off frequency of the waveguide type WR 28 used, it was possible when using suitable Gunn elements to generate oscillation up into the range of 35 GHz. Of course, it is also possible to use waveguide type WR 42. Electrically speaking, it is only the wavelength in the waveguide that changes, which means that the dimensions can be recalculated from those given in the drawings.

The use of a choke tuning allows a clear maximum to be found both when used as an oscilla-

tor, and as a detector. The conventional Gunn element (lower right) or Schottky diodes (below left) shown in Figure 1 can be used in this module.

## CONSTRUCTION

Figure 1 shows the complete module, which can be equipped with standard, or home-made flange connectors. For matching, one can use the well-known three-screw tuner (2 mm dia., spacing  $\lambda_{wg}/8$  to  $\lambda_{wg}/4$ ) – if this should be required – after which the output side of the module is lengthened by 1 to 2 cm.

In the **parts list**, those parts that can be taken from articles (1) and (2) are marked. Other parts that must be constructed are given in the drawings given in **Figure 2**. Other parts given in the list do not require drawings.

All solder joints are made with soft solder. If a flange is to be installed, it should be firstly soldered to the waveguide using a solder having a high melting temperature. The connection side of the flange can then be finished by milling or lathing. It may be sufficient to finish the surface with the aid of a wet emery cloth which is placed on a glass surface. Attention should be paid to obtain a constant pressure during the finishing process so that the flat surface is not rounded by mistake.

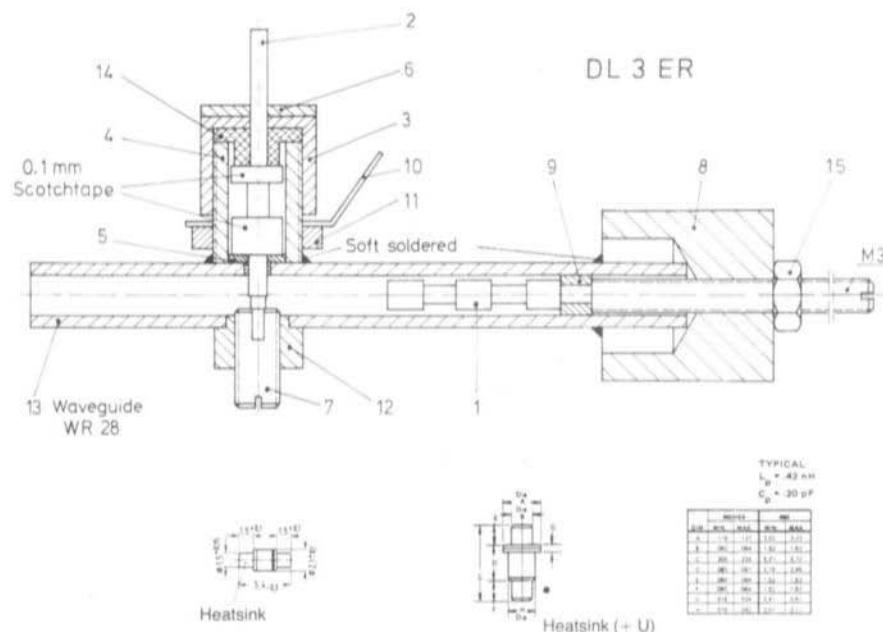


Fig. 1: A contact-less, tunable 24 GHz, which can be used as Gunn oscillator or as detector/mixer according to the semiconductor used.  
Dimensions below left: Schottky diode; below right: Gunn element

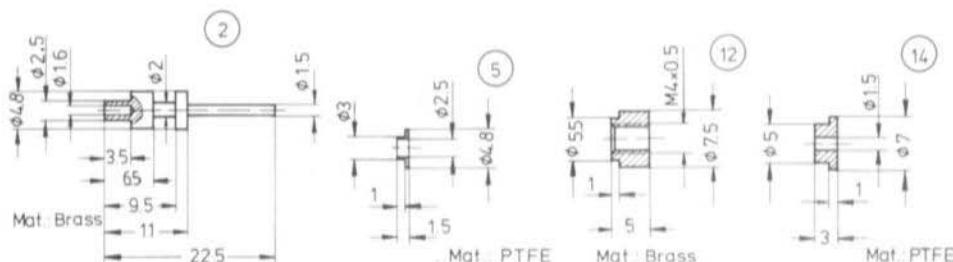


Fig. 2: A few parts for the construction shown in Figure 1; other parts see parts list.

Parts 4 and 12 are fixed and soldered together paying attention that the holes are exactly opposite to one another. For this reason, they should be drilled together previously using a 2 mm drill. Afterwards, it is possible to

drill the planned holes of the correct diameter. A centering tool should be made out of PTFE for part 4, which is then removed after soldering. A solder with a low melting temperature is required for this soldering process, and it is ad-

**Part Designation, Material, Dimensions Notes**

1	Tuning-choke system	as described in (2)
2	Choke for diode connection	see Fig. 2
3	Bicycle valve nut	as described in (1)
4	Bicycle valve shaft, 12 mm long, inner diameter 5 mm	
5	PTFE bushing	see Fig. 2
6	Isolating disk made from 1 mm thick PTFE, outer dia. 9 mm, hole 1.5 mm	without drawing
7	Diode screw from copper or brass M 4 x 0.5; 8 mm long, centered hole 1.6 mm dia. and approx. 5 mm deep	see Fig. 1
8	Mount for tuning choke	as described in (2)
9	PTFE spacing ring	as described in (2)
10	Solder tag with 7 mm hole	
11	Nut from bicycle valve	
12	Threaded copper or brass bushing	see Fig. 2
13	Waveguide WR 28 (R 320), approx. 55 mm long, with three-screw matching approx. 70 mm long	The length dimensions remain unchanged when using waveguide WR 42 (R 220)
14	PTFE bushing	see Fig. 2
15	Counter nut M 3	

visible for the flange soldering joints to be protected against too much heat by using a wet paper handkerchief. The soldering process is made most favorably using a butane gas flame, and carrying out the soldering process with a relatively small electric soldering iron whose tip has also been heated additionally by the flame.

The soldering of part 8 to the flange is less critical; parts 4, 12, and the flange should, however, be covered by wet paper handkerchiefs as a cautionary measure. The same solder as used for soldering parts 4 and 12 should also be used here, and the same measures applied.

The assembly is made as shown in Figure 1. The connection choke for the diode, or Gunn element is now insulated with a layer of Sello-tape. When using the module as Gunn oscilla-

tor, the required attenuator link should be soldered between part 2 and the ground solder tag to avoid parasitic oscillations: this is 22 nF in series with approximately 100  $\Omega$ . In some constructions, it is sufficient to use the 22 nF capacitor on its own, with others it is necessary for a further 10 to 50  $\mu$ F to be connected in parallel in order to suppress oscillation in the lower frequency range. This should be established experimentally and checked with the aid of an oscilloscope or TV-receiver.

The tuning choke is now inserted from the open side of the waveguide. The counter-sunk cone of approximately 120° allows it to be centered and fixed so that it is possible to insert a watch-maker's screwdriver and to place the threaded bolt into the associated hole after depressing the shaft of the choke.



## OPERATION AND RESULTS

The diode, or Gunn element should be inserted carefully in order to avoid a mechanical destruction of the component. The tuning with the aid of the choke system is very clear. In the case of resonators of this type using the  $H_{10}$ -wave, the waveguide chamber between semiconductor element and choke determines the frequency. The overall Q of this waveguide resonator determines the tuning width of the detector/mixer.

If a fine tuning is required, it can be made by inserting a metal screw – better PTFE – at a position of maximum electrical field strength. Such a position is approximately halfway between the semiconductor element and the choke, as well as in the center of the wide side of the waveguide. The tuning slope can be decreased by taking the tuning screw from the center of the waveguide and placing it more towards the edge.

When used as a Gunn oscillator, the module supplies an output power of approximately 10 to 50 mW according to the Gunn element. This is obtained with the most favorable heat dissipation, and matching.

When used as a detector, (e.g. when using a Siemens Schottky diode type BAT 14-121) the module can be used well in conjunction with the frequency meter described in (3), as well as for simple radiation pattern measurements on antennas. In order to increase the sensitivity, it is possible to add a simple horn antenna having a gain of approximately 15 dB.

The author has also used this module as a receive mixer successfully. The absolute noise figure is not known, since only an uncalibrated noise source was available. However, this allowed comparison measurements to be made. These measurements showed that when using the described module with a low-noise Schottky diode of the BAT 14-series, approximately the same sensitivity values were obtained as were exhibited by straight-through mixers equipped with 1N26 diodes.

Of course, the attenuator link to avoid parasitic oscillation of the Gunn oscillator must be removed for such applications, since this would otherwise short-circuit the IF-path.

## HEAT PROBLEMS

When using this module as a Gunn oscillator, it should be mentioned that the heat dissipation, when using the described construction under continuous operation, could cause problems. Even low-power elements such as the MA-49628 operate at a voltage of typically 5 V with currents of 100 to 200 mA. At the low efficiency of only 2 to 5 %, a power dissipation of 0.5 to 1 W results which must be dissipated. For this reason, the good heat conductivity of copper should be used whenever possible. Especially when operating this module with higher power Gunn elements, it is advisable to provide a conventional black-coloured heat sink, or to use a copper block as heat sink. Of course, it is possible to use both.

All parts that become noticeably warmer than their environment should be made black so that they can radiate the excessive heat. Since a silver-plated surface can hardly dissipate heat, one should only silver-plate the surfaces carrying RF-current in the inside of the module.

All these measures will be useless if the heat transition from semiconductor element to mounting screw is poor, because the hole is too large. A good fit, and possibly a little heat-conductive paste are required here. Since heat dissipates itself only very slowly (in brass much slower than in copper), the semiconductor crystal can have already exceeded the critical temperature of 250° before a temperature



increase can be felt on the heat sink. Feeling is just not sufficient when trying to solve heating problems; one must study especially the transitions having a low surface area carefully to see whether they can conduct heat. To clarify the situation, it should be noted that the heat load of the transition crystal/case is approximately 5 W/mm<sup>2</sup> in the case of low-power Gunn elements! In the case of the mentioned Gunn element, approximately 0.5 to 1 W must be conducted via approximately 8 mm<sup>2</sup>, if the whole surface of the anode is in direct heat contact in part 7. If only a part of the surface is in contact, the specific heat loading will be higher. Heat-conductive paste will not solve all problems encountered with bad fit; it must be used sensibly: The RF-contacts must remain free of heat-conductive paste due to the losses involved.

## REFERENCES

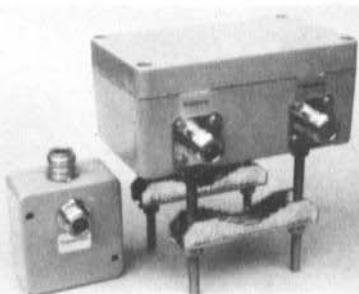
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